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Experimental study of damping characteristics of air, silicon oil, magneto rheological fluid on twin tube damper

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Abstract

This paper is inclined towards the study of damping characteristics of magneto rheological damper under different fluid environments i.e. Air damping, viscous damping and MR damping. The twin tube damper was designed to conduct the experiments and to analyze the dynamic behavior under these conditions. The results show that MR fluid has good damping characteristics than that of the other fluids due fluid-particle interaction and friction near fluid-structure interface. In addition it can provide high damping rate under the influence of magnetic field. Finally, the damping phenomenon of the MR fluid is discussed in depth to support the experimental results

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1. Introduction

The dampers or shock absorbers are widely used in automotive vehicles to dissipate the vibration energy of sprung and un-sprung mass under resonance conditions. Many types of dampers have been designed to meet the comfort and control requirements of passenger vehicles. The main types are Passive, Semi-active and active dampers. Among them, the passive damper is commonly used due to minimum cost and simple design principle. In passive

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damper the damping rate is fixed it cannot be changed where as in semi active damper the damping rate can be changed with a little amount of power. And in case of active damper, the damping rate can be changed with higher consumption of power.

The fluid inside the damper is usually throttled through the orifices at the piston due to pressure difference. The frequent throttling of fluid changes the velocity of the fluid to cause increase in temperature, thereby dissipating energy. The commonly used fluids for dampers are synthetic oil, mineral oil etc. During recent years the smart fluids such as MR and ER have been used inside the dampers to provide the variable damping under the application of current or voltage. Among the smart fluid MR fluid is much popular due high dynamic range**.** Emanuele et.al (2008) compared different semi active suspension system and concluded that MR fluid is better than ER fluid. These fluids are prepared using base fluid such as silicon oil, synthetic oil mixed with carbonyl particles in definite proportion**.** Carlson et.al (1999) investigated properties and application of magneto rheological fluid. Turczyn (2008) prepared magneto rheological fluid and studied the behavior of fluid under various conditions.

The dampers use normal synthetic oil which normally dissipates the energy due to the fluid structure interaction. And there are no other parameters involved to fasten the dissipation rate. So it is very important to compare the damping rate of different fluid system to optimize the product performance for given size of damper.

Nomenclature	
MRF	Magneto-rheological Fluid
ER	Electro-rheological
NI- PXI	National Instruments PCI extensions for Instrumentation
LVDT	Linear variable differential transformer

2. Damper design

The twin tube is most widely used design configuration for damper, as it serves many purposes of the damper. An inline accumulator was used to ease manufacturing process involved. John (1999) and Khan (2010) have given design criteria for various components of damper**.** The outer cylinder is filled with nitrogen to pressurize the fluid inside the damper. Fig.1 shows the design model of designed damper.

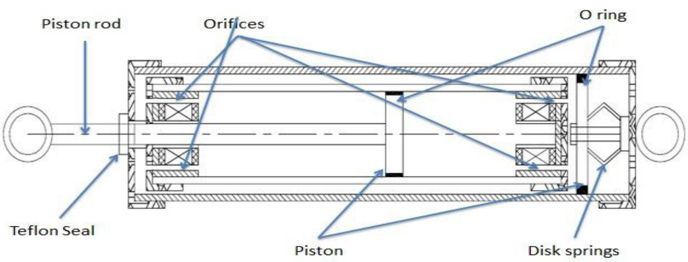

Fig.1. Twin tube MR damper

3. Experimental setup

The dynamic test of the damper was conducted by using APS 420 shaker on the test frame. The damper was connected in inline to the shaker table to avoid possible bending, shear and torsional moment in the piston rod. The instrumentation was used to acquire the physical quantities of the test. Fig 2 shows the experimental setup and the position of transducers. NI PXI-5401 function generator was used to produce sinusoidal loading condition to damper. The input and output force was measured using two Kistler force transducers and displacement was measured using Honeywell LVDT. 2000 samples of data were acquired at the rate of 2 KHz.

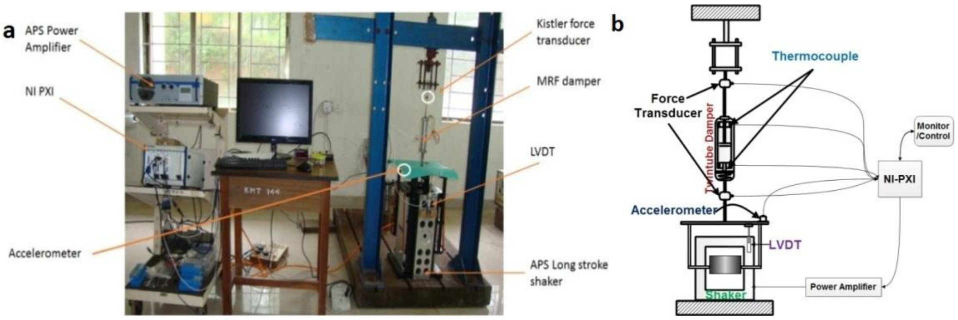

Fig.2 (a) Experimental setup for testing damper; (b) schematic diagram of the setup

4. Experimental results and discussion

The damper is being evaluated by its dissipation rate for given size of a damper. The amount of damping produced by the damper is proportional to the velocity. Hence the behavior of damping force versus the velocity of damper has to be studied carefully before using it for an application.

4.1 Experimental results

Using a dynamic test setup, a series of experiments was performed for different fluid conditions, by changing the loading frequency. The input frequency was also varied between 1Hz to 1.5Hz to study the effect of loading frequency. Moreover, the loading amplitude was kept almost constant, 1mm.

Also to investigate energy dissipation and damping rate for different fluid conditions on the designed damper, force - displacement and force - velocity plots are included.These are force vs displacement and force vs velocity graph at two different frequencies in Fig.3 and Fig. 4.

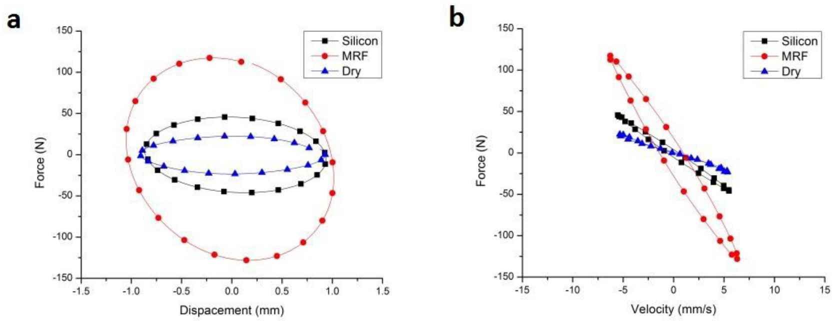

Fig.3 (a) Force vs Displacement at 1 Hz ; (b) Force vs velocity graph at 1Hz

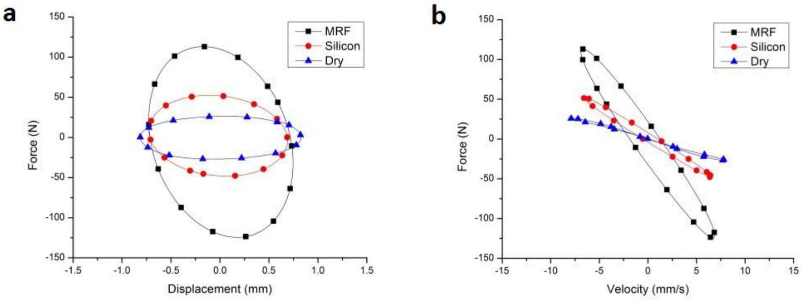

Fig.4 (a) Force vs Displacement at 1.5 Hz; (b) Force vs velocity graph at 1.5Hz

4.2 Discussions

The energy dissipated by the damper in a single cycle was measured by the area enclosed within the cycle, which is calculated by

$$E_d = \oint F dx \tag{1}$$

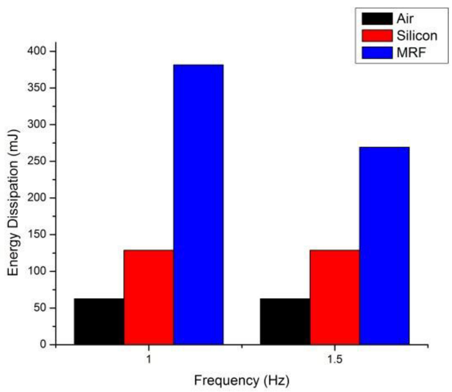

Fig.5 Energy dissipation v/s frequency

In case of MR fluid, the iron particle are dispersed in a career fluid.Hence there will be interation between the iron particles and the career medium during the fluid flow.In addition the these fluid also cause more friction force near the fluid structure interfaces.

From the fig.5 it observed that as the frequency increases, the energy dissipation decreases in the case of MR fluid but it remains same in the case of silicon and air.

The damping rate of MR fluid damper usually comes from three components i.e Viscous component, orifice component and friction component. The dissipation rate can be expressed below.

$$D_{total} = D_\eta + D_o + D_f \tag{2}$$

Where,

D_η is damping due to viscous component, D_o is the damping due to orifice, D_f denotes the dissipation coming from the interface of iron particle and career medium .The D_η further simplified to

$$D_\eta = \phi_C D_C + \phi_I D_I \tag{3}$$

Where ϕ_C and ϕ_I are percentage in volume of career fluid and iron particle respectively. D_C and D_I is the damping ratio of career fluid and Iron particle respectively.

D_f can be written as

$$D_f = nf\gamma \tag{4}$$

Where n is the number of particles in the volume of mixture, f is the frictional forces between the iron particle and fluid and γ is the strain rate.

At low frequency, all the factors inluence the damping rate but as the frequency increases the fluid show shear thinening effect inturn reduces the dissipation rate due to viscous component.(shear thining effect can be reduced by adding suitable additives)

5. Conclusions

In this paper the damping rate of the different fluid medium of a damper was compared. It is concluded that MR fluid has much better damping characteristics compared to the silicon oil and air. In addition this fluid can increase their damping rate under the influence of magnetic field. It is advised to use that MR fluid to increase the dissipation rate for a given size of damper. The further analysis of dissipation rate at two different frequency of operation, the dissipation decreased as frequency increased in the case of MR fluid but it remained constant for silicon and air damping.

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